

II. "Researches on the Chemistry of the Camphoric Acids."

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For some time past I have been engaged in the study of some derivatives of camphor, with the view of determining, if possible, with some degree of certainty the constitution of that body. I do not propose to enter now into any account of the present state of our knowledge as to the chemistry of camphor, but at once to bring forward something of my own experience on this subject.

Of part of the results which I have obtained I gave a brief account at the meeting of the British Association last year at Bath. This account had reference chiefly to some further evidence of the relationship of camphor to hexahydrometaxylene, and to the products of oxidation of camphoric acid by means of an alkaline solution of potassium permanganate. These researches were not published, and are not even yet completed.

On the other hand, I have made some additional experiments which I am anxious to bring forward now, as it may be some time before the whole series is finished.

The experiments to be described have reference to certain processes which resulted in the preparation of a new camphoric acid; and the remarkable properties of this acid contrasted with those of the ordinary camphoric acid throw considerable light on the nature of the isomerism subsisting between these bodies.

Camphoryl Chloride.

I have had occasion to prepare considerable quantities of camphoryl chloride, $C_{10}H_{14}O_2Cl_2$, by the action of pentachloride of phosphorus on ordinary camphoric acid. Camphoryl chloride was obtained originally by Moitessier ('Compt. Rend.,' vol. 52, p. 871), but only as a crude product, which he found to decompose on distillation. The substance may, however, be readily purified by distillation *in vacuo*, when it distils about $140^\circ C$. under 15 mm. pressure. There appears to be no difference in the product of the reaction however much pentachloride of phosphorus is used, provided the temperature be not raised above that of boiling water.

Chlorocamphoryl Chloride.

If, however, camphoric acid is heated with a large excess of pentachloride of phosphorus on a sand-bath in a flask provided with a reflux condenser, a new body of the formula $C_{10}H_{13}Cl_3O_2$, viz., chloro-

camphoryl chloride, is obtained. A further account of this body and its transformations I will reserve for a future publication.

The camphoryl chloride was prepared in order to attempt to reduce it to the lactone similar to the lactones obtainable from phthalyl and succinyl chlorides. It was not found possible to obtain a lactone under the various conditions of experiment from time to time adopted.

Action of Water on Camphoryl Chloride.

Circumstances, however, led to the consideration of a more simple reaction, namely, the action of water on camphoryl chloride. Moitessier had stated that this reaction was such as to give back camphoric acid. He means, presumably, the original dextro-rotatory acid, as he does not mention more than one. This acid is, in fact, formed, as will be shown subsequently, but only in very small quantity, and can only be separated from and recognised among the other products of the reaction after special treatment.

If camphoryl chloride obtained from ordinary dextro-camphoric acid is added gradually to about ten times its weight of hot water, there is formed about equal quantities of camphoric anhydride and a new camphoric acid, which rotates the ray of polarised light to the *left*. These two bodies are contained in the precipitate after cooling, and form by far the greater part of the product. Besides these, there is formed a small quantity of another substance more soluble in water, which separates from a strong hot aqueous solution as an oil, after a time solidifying. This is a mixture of the ordinary dextro-camphoric acid with the new lævo-rotatory acid. I will refer to this again later.

The camphoric anhydride and lævo-camphoric acid obtained in this reaction are readily separated by treatment with carbonate of soda in the cold, by means of which the lævo-acid is dissolved, leaving the anhydride untouched. This anhydride is converted into the ordinary dextro-rotatory camphoric acid by solution in hot caustic soda and precipitation by hydrochloric acid. I have been able to confirm de Montgolfier's observation that the camphoric acid obtained from the anhydride has a specific rotatory power of over $+48^\circ$. I have found $[\alpha]_D = +48.25^\circ$. (The determinations of rotatory power have been made throughout with a Laurent half-shade polarimeter, kindly lent me by Dr. Haldane, of the Physiological Department.)

Properties of the Lævo-camphoric Acid.

The lævo-rotatory acid obtained above has a rotation about equal, and of opposite sign to the dextro-acid. I have found $[\alpha]_D = -48.09^\circ$. I am convinced, however, that these two acids are not optically

opposite isomers, in the sense namely in which dextro- and lævo-tartaric acids are regarded as optically opposite.

In its ordinary properties the lævo-acid differs markedly from the dextro-isomer. It has a lower melting point, namely, 170° C., as compared with 185° C°. Again it yields a very soluble amorphous barium salt, the corresponding salt of the dextro-acid being also indeed very soluble but crystalline. A more remarkable distinction, however, is that the lævo-acid appears to have no corresponding anhydride. When subjected to the action of acetyl chloride, an important reagent employed by Anschütz for obtaining the anhydrides of dibasic acids, the dextro-acid readily and practically quantitatively yields its anhydride, which is insoluble in carbonate of soda. The lævo-acid, on the other hand, when treated in the same manner, yields a product almost completely soluble in carbonate of soda, from which the original acid of melting point 170° is recovered apparently unaltered.

Conversion of the Lævo- into the Dextro-Acid.

If, however, the lævo-acid be distilled, it boils about 294° C., yielding the anhydride of the ordinary dextro-camphoric acid, from which anhydride this acid may be obtained in the ordinary way.

Thus it appears possible to convert any quantity of the dextro-acid almost entirely into the lævo- through the intervention of the chloride, and any quantity of the lævo- back again to the dextro- by means of the anhydride.

Mixture of the two Acids.

Chautard obtained a lævo-camphoric acid by the oxidation of a lævo-rotatory camphor. This acid is described as possessing all the properties of ordinary camphoric acid, except that its rotatory power is of opposite sign. Further, when strong alcoholic solutions of the two acids are mixed there is a precipitation of crystals and a rise of temperature in the liquid.

The lævo-acid which I have obtained differs from Chautard's in other properties, and also in this, that when mixed with the dextro-acid in equal quantities in strong alcoholic solution there is no crystalline deposit and no rise of temperature.

On boiling down the alcoholic solution, a syrupy residue is left, which dissolves in hot water more readily apparently than either of its constituents. From the aqueous solution it separates partly as an oil, which after a time solidifies, and partly as crystals. Neither the solidified oil nor the crystals have a definite melting point, but both melt at a lower temperature than either of the component acids. Hence the two acids do not appear to form any definite compound camphoric acid.

Separation of the Mixed Acids.

Anschütz's acetyl chloride reaction furnishes a particularly neat method of separating the two acids. The anhydride of the dextro-acid formed by the action of the acetyl chloride is separated from the apparently unaltered lævo-acid by treatment with carbonate of soda, which dissolves only the latter.

Nature of the more soluble Syrupy Product of the Action of Water on Camphoryl Chloride.

This substance, which resembled the mixture of dextro- and lævo-acids above described, was subjected to the same process of separation, by which exactly the same products were obtained.

Thus the action of water on the acid chloride is such as to give about equal quantities of lævo-camphoric acid and the anhydride of dextro-camphoric acid, a small portion of latter being further converted into the acid.

Optical Activity of Camphoryl Chloride and Camphoric Anhydride.

It might be supposed, from the circumstances just mentioned, that camphoryl chloride which yields both dextro- and lævo-camphoric acids would be itself inactive. This, however, is not the case. I have always found camphoryl chloride to be lævo-rotatory, though I have not found a perfectly constant number to express its value. For the undiluted substance I have found $[\alpha]_D = -3.0^\circ$, and -3.6° , while for the substance dissolved in crude benzene the rotation is about twice as much, viz., $[\alpha]_D = -7.1^\circ$ and -8.3° ; the latter value being obtained with the same specimen of camphoryl chloride which gave a rotation of 3.6° when undiluted. The rotation is, indeed, greater than that of camphoric anhydride, a substance which yields only one camphoric acid. I have found the specific rotation of camphoric anhydride in pure benzene to be -3.7° , and very little different in the same benzene which was employed for the camphoryl chloride. De Montgolfier has given a higher value, $-7^\circ 7'$, for camphoric anhydride, which I am unable to confirm.

Theoretical Considerations.

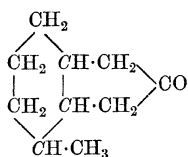
If we wish to interpret rightly the foregoing facts, we shall, I think, find it impossible to regard the lævo-camphoric acid as the optically opposite isomer of the ordinary acid. On the other hand, there would appear to be a probability, almost amounting to certainty, that these two acids are related to one another as maleic and fumaric acids, the dextro-camphoric acid corresponding to maleic and the lævo- to fumaric acid. The isomerism is further complicated by the presence of rotatory power which requires the existence of two other

isomers which shall be the optically opposite isomers of these two. In this latter case, therefore, the two acids will also be related, as maleïc and fumaric acids, but the lævo-acid will correspond to maleïc and the dextro- to fumaric. This lævo-camphoric acid is without doubt the acid which Chautard obtained by the oxidation of lævo-camphor, and the fumaroid dextro-acid I hope to obtain from it by the hydrolysis of the acid chloride.

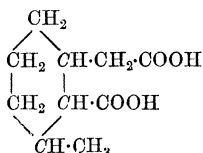
Now, accepting unreservedly Van't Hoff's carbon-atom hypothesis, we find that the isomerism of the camphoric acids is not explained by different structural formulæ, but rather by one and the same structural formula, admitting of at least four different arrangements of the atoms in space. There will be then two conditions attached to such a structural formula: (1) Either it will contain two doubly-linked carbon-atoms, each of them being united to two different groups, and one of these groups containing also an asymmetric carbon-atom; (2) or the formula may consist of a closed chain of carbon-atoms, of which two or more are asymmetric. In the latter case, it is necessary to mention a further restriction, namely, that when there are only two asymmetric carbon-atoms in the ring, there must not be symmetry in the formula, or, in other words, the image of neither isomer must be identical with its object (see 'Phil. Mag.,' 1888, vol. 26, p. 426). It is the more necessary to mention this restriction as it applies to Wreden's formula, a formula which does not admit of rotatory power in the maleinoid acid, that is, in the ordinary camphoric acid.

Turning now to some of the formulæ proposed for camphoric acid by different chemists, we find that in general they satisfy one or other of the conditions before mentioned. But Kekulé's formula, which fulfils the first condition, and Kachler's, which satisfies the second, cannot be accepted, on the ground that they do not represent camphoric acid as a derivative of hexahydrometaxylylene. Wreden's formula which does thus represent camphoric acid does not, as I have just mentioned, satisfy the restricted second condition. Armstrong's formulæ satisfy the second condition, and also represent camphoric acid as a derivative of hexahydrometaxylylene, but Armstrong's formulæ appear to me liable to objection on the ground of the formula for camphor from which they are derived. These formulæ represent camphor either as not containing a ketonic group, or if it contain a ketonic group as containing also a closed chain of four carbon-atoms. Now, we know no instances of stable rings of four carbon-atoms, if indeed we know instances of such rings at all; and it is unlikely that camphor is the one exception to what may be regarded as a general rule.

The formulæ which I have proposed for camphor and camphoric acid appear to be opposed by no facts, and also explain perfectly the isomerism of the camphoric acids. Camphor is represented by the formula—

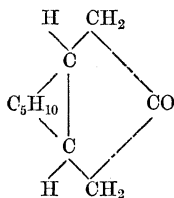


and camphoric acid by the formula—

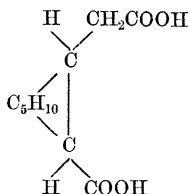


(The asymmetric carbon-atoms are in italics).

Now the ordinary camphoric acid being the maleinoid acid has the two groups (COOH) and ($\text{CH}_2 \cdot \text{COOH}$) on the same side of the ring plane of the six carbon-atom nucleus. Hence in camphor, as we should naturally have supposed, the grouping, $\text{CO} < \begin{smallmatrix} \text{CH}_2 \\ \text{CH}_2 \end{smallmatrix}$, is also attached on one side of and not across the ring plane—

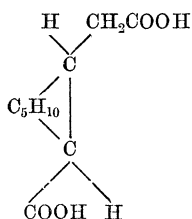


(dextro- and lævo-camphor).



(dextro- and lævo-ciscamphoric acid).

Again the lævo-fumaroid acid has the carboxyl and (CH_2COOH) groups on opposite sides of the ring plane.



(dextro- and lævo-transcamphoric acid).

On the other hand, Chautard's lævo-camphoric acid, being obtained directly from a lævo-camphor, will have the respective groups on the same side.

Nomenclature.

We may adopt the nomenclature introduced by von Baeyer to distinguish the hydroterephthalic acids. Ordinary camphoric acid then is dextro- and Chautard's acid lævo-ciscamphoric acid, the prefix *cis* indicating that the carboxylic groups are on the same side of the ring plane.

The new acid again, which I have described in this paper, is the lævo- and the acid yet to be discovered will be the dextro-transcamphoric acid, the prefix *trans* implying that the groups which govern the isomerism are on opposite sides of the ring plane.

It will be noticed that the formulæ which I have adopted require the existence of another series of two camphors (dextro- and lævo-) and four camphoric acids; but of the existence of these we have as yet no evidence.

[*Postscript, Dec. 2nd, 1889.*—Since the above was written, my attention has been drawn to a paper by M. Friedel in the 'Comptes Rendus' of last May, in which he describes a lævo-camphoric acid obtained from the substance known for some time as mesocamphoric acid. This lævo-acid appears to be the same as the one I have just described, and the mesocamphoric acid to be a mixture of the lævo- with the original dextro-acid. Thus mesocamphoric acid must no longer be regarded as a distinct isomer.]